MAN. 38

AGRICULTURAL WASTES AS CEMENT KILN FUELS

GENSTAR CEMENT LTD.

MC NUMBER 13177

82.145
MARCH 1985

MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources — oil and natural gas — are becoming less accessible and more costly. However, Canada is well-endowed with renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminated March 31, 1984. The Agreement was dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program had a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

Opinions contained in this report are those of the author(s) and are not necessarily those of the Manitoba Department of Energy and Mines, or Energy, Mines and Resources Canada.

Use of company names, brand names or trademarks is made for informational purposes only and does not constitute endorsement or recommendation over similar products or services.

EXECUTIVE SUMMARY

Genstar Cement Limited of Winnipeg received funding under the Canada/Manitoba Conservation and Renewable Energy Demonstration Agreement (CREDA), to evaluate the use of combustible solids, particularly wastes, as fuel supplements for a natural gas-fired cement kiln.

A pilot scale pneumatic feed system was designed and built to deliver solid fuels in suspension into the natural gas flame.

The test fuels studied were flax shives (a waste byproduct from flax milling), wood sawdust and shavings, Woodex compressed wood pellets, peat, ground rubber and petroleum coke.

Flax shives were found to offer the best combination of fuel performance, cost and availability. Substitution rates of close to 20% of the natural gas were achieved; higher rates were prevented by problems with bridging and jamming of the equipment caused by fuel contamination (clay, tramp metal) and by the intractable nature of the shives.

Based on experience from the pilot trials, Genstar built a permanent solid fuel feed system with upgraded heavy-duty equipment, at an approximate capital cost of $500,000 (1984). Flax shives are being used as the main fuel supplement.

Operation at the design substitution rate of 20% for this system should yield a simple payback of less than one year, assuming regular cement production levels are maintained. Annual savings of approximately $700,000 in natural gas are possible under these conditions.

SOMMAIRE

La société Genstar Cement Limited de Winnipeg a reçu une subvention dans le cadre du Programme (Canada-Manitoba) de démonstration des énergies renouvelables et des économies d'énergie (PDÉRÉÉ) pour étudier l'usage des matières solides, notamment les déchets, comme combustibles d'appoint pour l'alimentation des fours à ciment chauffés au gaz naturel.

La société a donc conçu et fabriqué un système expérimental d'injection pneumatique de combustible solide en suspension dans la flamme de gaz naturel.

Les matières combustibles suivantes ont fait l'objet d'essais: capsules de lin (sous-produit du battage du lin), sciure et copeaux de bois, granules de bois comprimé Woodex, tourbe, caoutchouc broyé et coke de pétrole.

Les capsules de lin ont donné le meilleur compromis entre le rendement énergétique, le coût et la disponibilité. Des taux de substitution du gaz naturel de près de 20 % ont été réalisés. Il aurait été possible de réaliser des taux plus élevés n'eut été les problèmes d'obturation et de blocage de l'équipement causé par la contamination du combustible (argile, résidus métalliques) et la difficulté de traitement des capsules.

À l'issue des essais, Genstar a mis au point un système permanent d'alimentation par combustible solide, utilisant un matériel plus puissant. Le coût approximatif en capital s'est élevé à 500 000 $ (1984). Les capsules de lin constituent le principal combustible d'appoint.

L'exploitation du système au taux de substitution de 20 % devrait permettre d'obtenir un délai de récupération de moins d'un an, au taux simple, à condition que l'on maintienne un niveau normal de production de ciment. Dans ces conditions, il est possible de réaliser des économies de l'ordre de 700 000 $ dans la consommation de gaz naturel.

TABLE OF CONTENTS

	EXECUTIVE SUMMARY	(i)
1.0	INTRODUCTION	1
2.0	SYSTEM DESCRIPTION	3
	2.1 PLANT DESCRIPTION	3
	2.2 PILOT FEED SYSTEM	3
3.0	TEST FUELS	6
4.0	EXPERIMENTAL PROCEDURE	7
5.0	EXPERIMENTAL RESULTS	8
6.0	DISCUSSION OF RESULTS	8
	6.1 FEED SYSTEM PERFORMANCE	8
	6.2 TRIAL FUEL PERFORMANCE IN THE KILN	10
	6.2.1 CONSUMPTION	10
	6.2.2 CLINKER QUALITY	10
	6.2.3 EMISSIONS	11
7.0	FUEL COSTS AND AVAILABILITY	13
8.0	CONCLUSIONS AND RECOMMENDATIONS	14
9.0	PERMANENT SYSTEM DESCRIPTION AND COST	16
10.0	REFERENCES	19

LIST OF TABLES

TABLE 1	FUEL CHARACTERISTICS	6
TABLE 2	SUMMARY OF EXPERIMENTAL RUNS	9
TABLE 3	SUPPLEMENTAL FUELS - COST AND AVAILABILITY	13

LIST OF FIGURES:

FIGURE 1	WET PROCESS CEMENT MANUFACTURE	4
FIGURE 2	EXPERIMENTAL SOLID FUEL FEED SYSTEM	5
FIGURE 3	LIVE BOTTOM HOPPER	17
FIGURE 4	GENSTAR SOLID FUEL	18

1.0 INTRODUCTION

The crucial step in the cement manufacturing process occurs in the rotary kiln. Here a precise blend of raw materials is "burned" for a period of approximately three hours at temperatures up to 1550^{o}C to form cement clinker. The burn consumes tremendous amounts of energy, such that kiln fuel represents the largest single operating cost in the process.

Rising fuel prices have led a number of companies to experiment with the use of various low cost combustible wastes as substitutes for fossil derived kiln fuels. Examples of these wastes are refuse derived fuel (RDF) (1), used solvents, oils and other liquids (2) (3), and shredded rubber tires (2). After analysis of the waste market in Manitoba, Genstar Cement Ltd. of Winnipeg, ran a series of preliminary experiments using wheat and oat straw as substitute fuels to reduce the consumption of natural gas in the kiln. Agricultural wastes were a logical choice for use at the Winnipeg plant, with its access to a large resource of these materials. Straw bales were shredded and the chopped material was blown into the kiln flame via a stovepipe temporarily fitted through a service access door. Approximately 10% (energy basis) of the natural gas could be displaced by the straws, the amount limited by the capacity of the feed system. Soon after these trials were completed Genstar obtained access to a plentiful, concentrated, and low cost supply of another agricultural waste, flax shives. Flax shives are the residue left after the fibre is removed from flax straw for the manufacture of flax (rag) papers.

As a result of these developments Genstar designed a more flexible pilot system for experimentation with solid fuel firing; one which would allow delivery of the fuels to the kiln flame in a more controlled and measureable manner, with a design capacity for greater than 30% replacement of natural gas. The company applied for and received funding under the Canada/Manitoba Conservation and Renewable Energy Demonstration Agreement (CREDA), to assist the operation of the pilot system for the purpose of establishing the technical and economic feasibility of using agricultural wastes as supplementary fuels.

Subsequent to the CREDA-funded trials with flax shives, Genstar also ran several other alternative solid fuels through the system for evaluation; wood shavings, compressed wood pellets (Woodex), peat, petroleum coke, and shredded rubber tires.

This report will discuss the results of the flax shive experiments and, for comparison, some of the results obtained with the other solid fuels. After the experimental trials were completed, Genstar designed and installed a permanent solid fuel feeding system. A description of this equipment, and preliminary operational results are also included.

2.0 SYSTEM DESCRIPTION

2.1 Plant Description

The Genstar Cement Limited Winnipeg plant, built in 1965, has an annual production capacity of approximately 300,000 tonnes of cement. It has one F.L. Smidth wet process kiln measuring 138 metres long by 4 metres in diameter. The wet process is illustrated in Figure 1.

Historically the kiln has been fired with natural gas as the primary fuel, with a typical average consumption of 5.95 GJ/tonne clinker (about 42 Nm^3 natural gas/tonne clinker). The present burner pipe projects approximately 4 metres into the discharge end of the kiln, and has a 10.2 cm (4 inch) diameter feed tube through the centre into which a Coen burner for No. 6 (Bunker "C") fuel oil can be inserted. The natural gas and primary combustion air are fed through tubes positioned concentrically around this (see Figure 2). Due to the very high cost fuel oil is seldom used as an alternative and only when the natural gas supply is interrupted. Waste oils have in the past been fired in the kiln, however, the supply of these has been too limited and irregular to allow a significant displacement of natural gas.

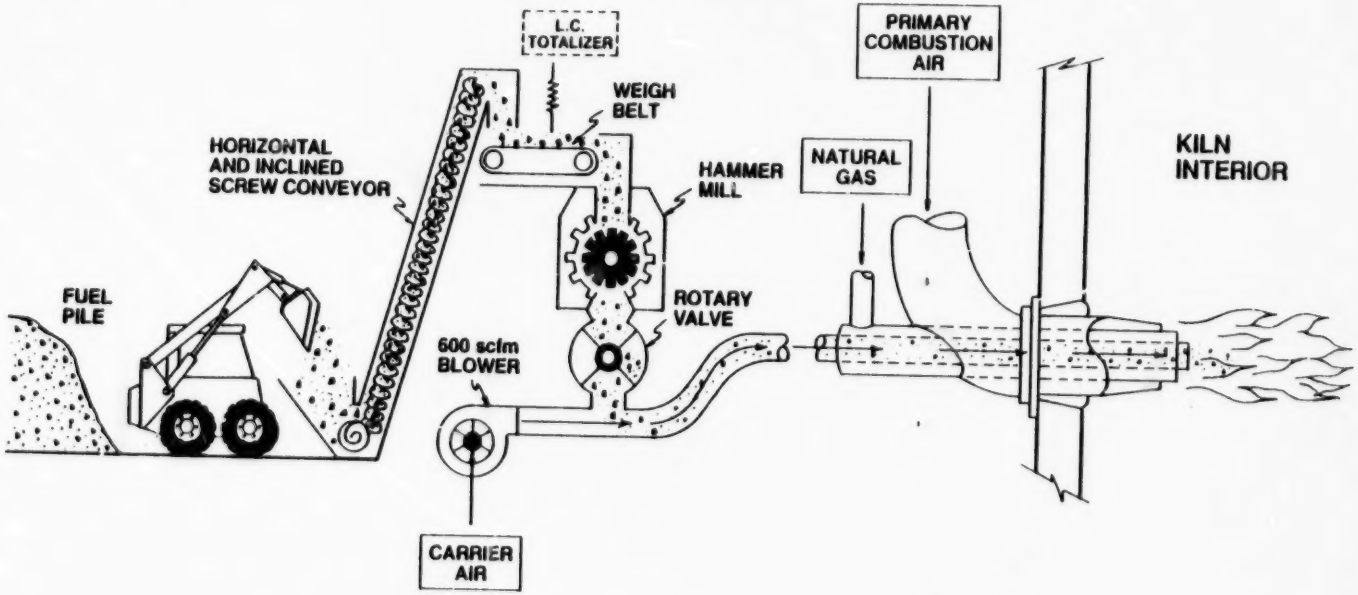
2.2 Pilot Feed System

Minimal conversion of the kiln burner was required for testing the supplementary solid fuels. With the oil burner head removed, the central oil feed tube provided an effective conduit so that flax shives or other solid fuels could be blown directly into the centre of the natural gas flame where, with correct momentum, they would burn in suspension.

The pilot system for delivering solid fuel to the kiln burner is illustrated in Figure 2. It is a simple design consisting of equipment for metering and smoothing the flow of solid fuel into a pneumatic transport line connected to the burner. A bucket loader was used to transfer the fuel from the storage pile into a variable speed ratioed horizontal and inclined screw conveyor (a modified grain auger was used). The fuel dropped onto a weighbelt and then into a hammermill. The hammermill was used to break up lumps in the fuels, and was not intended for size reduction, although this did occur with Woodex pellets used in subsequent trials. Since no screens were used in the hammermill the fuel passed directly into the rotary valve, which fed the fuel into a 10.2 cm (4 inch)

WET PROCESS CEMENT MANUFACTURE
LIMESTONE
- CRUSH
- SLURRY
CLAY
- WASH
- SLURRY
SILICA SAND
IRON ORE
RAW GRINDING BALL MILL
SLURRY STORAGE
KILN FUEL
ROTARY STEEL KILN 1500°C
AIR COOLING
CLINKER STORAGE
CLINKER
GYPSUM
FINISH GRINDING BALL MILLS
CEMENT STORAGE SILOS

Figure 1



EXPERIMENTAL SOLID FUEL FEED SYSTEM

Figure 2

steel pneumatic pipeline. The fuel was then carried some 60 meters to the burner head, where it was blown through the central feed tube into the kiln flame. The carrier air stream was produced by a 40 Hp (600 scfm rated) blower mounted under the kiln (for some preheating of the air) and located upstream from the rotary valve.

Some variations of this flowpath were tried during the course of the trials. For example, the hammermill was moved to a position ahead of the weighbelt. This was done in an attempt to reduce plugging of the hammermill caused by rotary valve blow-by. However, the flow pattern illustrated in Figure 2 was the one used for all of the flax trials, and proved to be the ultimate model for the permanent feed stystem now being operated at the plant.

3.0 TEST FUELS

The solid fuels used in these experiments are listed in Table 1, along with some of their pertinent characteristics.

TABLE 1

TABLE I – Fuel Characteristics

Material	Density kg/m³	Typical Moisture % (as delivered to plant)	Measured Heat Content Megajoule/kg (Gross)	Calculated Required Feed Rate tonne/hr**
Flax	192	9-20	17.7 @ 12% H_2O	4.7
Wood Shavings	128	18.4	17.4 @ 10% H_2O	4.8
Peat Moss	120	52.4	16.6 @ 12% H_2O	5.0
Wood Pellets	600	7	18.7 @ 7% H_2O	4.0
Rubber	400	1.3	38.5 @ 1.3% H_2O	2.2
Petroleum Coke	560	18-21	27.7 as delivered	3.0

**assuming 30% displacement, corrected to lower heating value at measured moisture content

The flax shives, wood shavings, and ground rubber were obtained from local industries. The shives were useable as received as they are chopped to less than 2 cm in length during the milling operation used to produce flax fibre. The peat was in the form of dust collector fines and general plant spillage from a horticultural peat moss operation near Winnipeg. Woodex pellets were imported from out of province by a local distributor and the petroleum coke was trucked from a Regina, Saskatchewan refinery. The fuels were stored in open piles on the plant grounds.

4.0 EXPERIMENTAL PROCEDURE

A test run procedure consisted of the following: The weighbelt was calibrated and then the blower, rotary valve, weighbelt, hammermill and the screw conveyor were started in that order. The hopper was filled and the fuel flow to the rotary valve was measured. Upon ascertaining the flow rate, the console operator in the plant control room was radioed so that natural gas flow could be reduced accordingly and fan draft adjusted if necessary. The console operator also recorded gas and slurry meter readings before and after the run. The fuel feed rate was determined from the weighbelt readings, and recorded every half hour during a run. The total amount of solid fuel used during a run was recorded for runs one to eight from a totalizer connected to the weighbelt.

Samples of clinker were taken from each fuel burning and were analyzed for comparison to the standard composition of clinker from a 100% gas firing. Clinker was analyzed for C_2S (cement industry abbreviation for dicalcium silicate), C_3S (tricalcium silicate), C_3A (tricalcium aluminate), and C_4AF (tetracalcium aluminoferrite), SO_3, alkalis and chlorides.

Plans to measure stack emissions for each fuel run were abandoned when a series of malfunctions occurred in the precipitators just prior to the trials and could not be rectified in time to allow meaningful data to be obtained.

5.0 EXPERIMENTAL RESULTS

Numerical results of fifteen experimental runs are summarized in Table 2.

6.0 DISCUSSION OF RESULTS

6.1. Feed System Performance:

A number of equipment problems were encountered. The usual causes of run interruptions and terminations were jamming and plugging. The longest uninterrupted run length, 10.5 hours, was obtained with Woodex pellets; the longest uninterrupted runs with flax shives were both 7 hours.

Poor system durability was a result of a combination of the light duty design of the front end equipment and the intractable nature of the flax shive supply. The conveyor, weighbelt and rotary valve did not perform adequately at the high volumetric throughputs required to feed the flax shives at energy substitution rates greater than 20% (equivalent to about 3 tonnes/hour). The shives had a tendency to bridge and, as previously mentioned, to compact to the extent that test equipment would shear. Also, the flax shive supply contained a large amount of tramp metal and clay soil picked up during delivery, storage and transfer to the feed hopper. These contaminants caused the majority of the instances of jamming and plugging when this fuel was run, and undoubtedly contributed to the early wear of the rotary valve. A vibratory screen and magnet on the front end of the system somewhat reduced the contaminant levels in later runs. Proper attention to design and storage management should eliminate many of these problems in a permanent installation.

On the positive side it should be noted that the shives, when stacked properly, can be stored outside with no protection and still maintain an equilibrium moisture content of approximately 8% within the pile. The material flowed well through the pneumatic feedline, with no drop out or plugging at test feed rates (plugging of the pneumatic line was caused by the contaminants).

TABLE 2 – Summary of Experimental Runs

Run Number	Fuel	Tonne Clinker Produced	MJ consumed/ Tonne Clinker (Natural Gas)	MJ/Tonne (Solid Fuel)	MJ/Tonne (Total)	% Supplement of Natural Gas	Clinker Analysis**	
							SO_3 (%)	Alkali (%) (as Na_2O)
*	natural gas	—	5950	—	5950	0	0.2	0.75
1	flax	286	4 800	960	5 760	16.7		
2	flax	289	5 000	1 161	6 161	18.8		
3	flax	304	5 600	1 230	6 830	18.0		
4	flax	523	5 360	1 308	6 668	19.6	0.3	0.80
5	flax	497	5 458	830	6 288	13.2		
6	flax	366	5 870	977	6 847	14.3		
7	flax	301	5 435	1 117	6 551	17.1		
8	wood shavings	218	4 984	1 133	6 117	18.5	0.55	1.08
9	wood pellets	427	5 206	1 497	6 307	23.7	0.40	1.10
10	wood pellets	211	3 667	2 641	6 308	41.9	—	—
11	peat moss	332	5 556	181	5 737	3.2	0.20	0.75
12	peat moss	122	5 545	153	5 698	2.7		
13	petroleum coke†	—	—	—	—	—	—	—
14	rubber	215	4 434	906	5 340	17.0	0.20	0.65
15	petroleum coke†	—	—	—	—	—	—	—

*30 day average gas consumption preceding test

†material plugged the feed system within 20 minutes

**no significant changes in C_2S, C_3S, C_3A and C_4AF were found

Woodex pellets and shredded rubber fed most easily of all of the fuels. However, their energy density was so high that the turn-down capacity of the system was strained and control of the feed was difficult. There were other notable problems with the comparison fuels. Dust was a health and safety hazard, when wood shavings, Woodex and peat were run. Wood shavings and especially peat and petroleum coke had excessive moisture contents that could not be reduced by equipment on hand. Essentially the peat was fed through to the kiln only as a means of disposal. The petroleum coke was so viscous that it plugged the feed system within 20 minutes.

6.2. Trial Fuel Performance in the Kiln

A kiln fuel must suit a number of criteria, for example:

- burning should be even at a flame temperature high enough to maintain the maximum reaction temperature (1550^{o}C), but not too high as to burn the clinker.
- control of free oxygen (typically 1.5% in the kiln exhaust) should not be affected.
- burning should not produce chemicals in the volatiles or ash that will negatively affect clinker quality.
- burning should not create any unmanageable emissions, especially toxic metals or organics in either the exhaust or the product.

The flax shives met these criteria within the limitations of the testing. Kiln performance of the various fuels is summarized in Table 2.

6.2.1. Consumption:

The gas consumption figures were calculated from meter readings taken in the control room. The solid fuel energy consumption values were derived by multiplying the totalized (cumulative) weight by the gross heating value measured for the fuel (given in Table 1).

The increased rate of overall fuel consumption in runs 2 through 10, in comparison with the 30 day proceeding average for natural gas (5950 MJ/tonne), was found to be largely due to the use of an unusual

type of limestone during these runs. The unsupplemented natural gas consumption for this same period was also higher, averaging 6,160 MJ/tonne. This consumption has been attributed to the fineness of the limestone. The excess dust increased the circulating load, giving rise to a cooler burning zone and higher back end temperatures. Energy consumption fell when the conventional limestone was once again used (runs 11 to 15). While the introduction of this uncontrolled variable has unfortunately affected the comparative value of these results, some general conclusions can be made.

The total energy requirement does appear to rise when flax is burned as a supplement. The average consumption for seven flax runs was 6,447 MJ/tonne, versus the average of 6,160 MJ/tonne for unsupplemented natural gas runs made during the same period. This increase may be attributable to a number of factors. In some runs the solid fuel contained a large amount of non-combustible contamination (mainly clay) which was nevertheless counted as fuel in the totalized weight. The effect of compensating for these contaminants would be to lower the calculated overall consumption. One would also expect that the use of an unoptimized burner head would lower the combustion efficiency of the solid fuel. It is notable that supplemented and unsupplemented average consumption values for these trials are as close as they appear to be.

6.2.2. Clinker Quality

No significant changes in C_2S, C_3S, C_3A and C_4AF were measured for in any of the trial burns. Changes in SO_3 and alkalis are listed in Table 2. Clinker analyses indicate that the shives burned satisfactorily with less apparent effect on clinker quality than the other fuels. The appearance of the clinker indicated no reducing conditions and the measured changes in chemical composition would not have any significant effect on the clinker or cement quality. It was expected that flax shives would have a minimal effect because silica (a cement raw material) makes up the majority of the ash content of shives.

The increase in alkali content from the wood shavings burn would have an effect of decreasing cement strength. Severe reduction of the clinker

was observed in the high rate Woodex pellet run (No. 10, Table 2). There was indication that suspension was not maintained during the burning. Alkali levels decreased slightly and the clinker appeared overburned when rubber was used as a supplement. These were a result of the kiln running hotter than normal.

6.2.3. Emissions

The inability to obtain a meaningful measure of kiln emissions unfortunately allows only speculative comments to be made here. With this caveat noted it can be said that one could expect most of these fuels to be more benign than some of the wastes being tested at other facilities, where risks from lead and chlorine compounds in oils, solvents and RDF have been determined (4). Dioxin production has been found to be a risk during kiln upsets that occurred during some supplementary waste fuel burns (4).

Flax shives (and other straws) appear to be "cleaner" fuels going into the burn; the greatest concern would likely be with the effect on particulates emission. However, some caution to consider the history of any crop waste may be necessary. For example, there is a possibility that agricultural wastes will contain accumulated heavy metals, and/or chlorine from the soil and from fertilizer, herbicide, and pesticide residues. It is not likely that these would reach the levels found to be of danger in other fuels, and these are not considered a problem with Manitoba crop wastes.

The other fuels from this experiment will not be discussed, except to say that increased sulphur oxide emissions would be expected if petroleum coke (5.2% sulphur content) were burned.

7.0 FUEL COSTS AND AVAILABILITY

7.1 The cost per megajoule and annual available amounts are compared in Table 3.

TABLE 3

TABLE 3 – Supplemental Fuels – Cost and Availability

Fuel	$/Megajoule (Winnipeg, October 1983)	Availability (tonne/year)	Requirements* (tonne/year)	Transportation and Stockpiling
natural gas	0.004500	in excess of all requirements	varies with throughput	on demand
flax shives	0.000885	30 000	16 400	October through April
wood pellets	0.002917	in excess of all requirements	15 500	on demand
wood shavings	0.000924	700	16 700	on demand
petroleum coke	not available	9 000	6 300**	on demand
peat moss	not available	500	17 500	on demand
rubber	0.000947	1 500	7 500	on demand

*assume 1/3 gas replacement except for** **assumes 1/5 gas replacement due to high sulphur

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Wood shavings, peat moss and rubber can be virtually ruled out as high rate supplements because of their low availability, at least for the near term. There is potential in Manitoba for a fuel peat mining operation that could supply a sufficient amount. However, the costs of drying to and maintaining a suitable moisture content, and the problem with dust would be important considerations working against the adoption of this fuel. In addition, pilot trials of peat at higher feed rates still have not been made to determine energy consumption, clinker quality and emissions. The cost of shredding has not been included in the rubber cost listed in Table 3. If the listed available supply were to be fully utilized the purchase cost of a shredder (capital cost approximately $500,000) and its operating costs would have to be added to the fuel cost.

8.2 Petroleum coke appears attractive in terms of supply volume and heat content. Unfortunately the coke in its available form is too wet to feed or burn properly in the present system, and it is expected that a means of drying into a suitable form will prove too costly. A system to feed the coke as a slurry in oil would require a new burner and there is still the worry of moisture content. The sulphur content of the fuel would also limit its use.

8.3 Woodex offers several advantages as a supplementary fuel. It is easy to process, is readily available and has a high energy density. These advantages provide Woodex with the greatest potential of all the fuels tested for supporting very high rates of natural gas substitution (up to 100% is conceivable). A combination of particle size reduction and burner head reconfiguration would be necessary to produce a system capable of maintaining suspension burning of this fuel at high rates of feed. More analysis of the effects of burning Woodex on kiln materials, clinker quality and emissions is also required. The effect of ash content on cement quality would be of particular concern.

The major disadvantage of Woodex is cost; the current pricing policy is to commodity base at approximately 75% of the price of natural gas. With this pricing structure, the maximum rate of return on investment, which occurs at a 100% level of substitution of natural gas, is still marginal. When one considers the likelihood that a 100% solid feed system would have a shorter average on-stream time than a gas or dual fuel system, this option appears even less attractive.

8.4 On balance, of the fuels tested, flax shives offered the best combination of low cost, adequacy of supply, and kiln performance. While the shives proved very difficult to handle in the pilot runs, most of this difficulty was the result of inexperience. Genstar staff were confident that with the experience gained by the trials a reliable feed system based on the pilot design could be built to deliver flax shives at a high rate. Reliability could be achieved in large part by management of the supply to reduce contamination and by specification of more rugged, higher capacity equipment at the front end of the feed system. Storage pile maintenance will likely prove to be a major task. Under current arrangements, almost a full year's supply, 15,000 tonnes, would have to be stockpiled because of a limited production season. Fortunately, with proper piling the shives require minimal protection from the elements and spontaneous combustion is not a problem.

8.5 The shives have additional advantages in comparison to most of the other trial fuels: moisture accumulation and dust propagation are lesser problems and the material burns well without significantly affecting clinker quality. It is expected that the shives will burn well with the present burner even at a substitution rate of 33%, if this could be achieved with the feed system. The low density and aerodynamic shape are conducive to maintaining suspension at higher rates.

8.6 Other agricultural wastes could be used as fuel; most, including wheat, corn and barley straw, and sunflower hulls and pulp have similar or even higher heat contents (5). In Genstar's case, the particular advantage of flax shives over other agricultural wastes is the ready availability of a concentrated supply. The costs of field collection, chopping to a feedable size, and transport to a site near to the plant are already subsidized by the customers of the primary flax product, flax paper. Finally, there is, at this time, no competitive market for the shives as there may be for other agricultural wastes. Shives have little value as tillage and are usually burned in the field to the detriment of the local environment.

9.0 PERMANENT SYSTEM DESCRIPTION AND COST

Since completion of the pilot runs Genstar has designed and built a permanent solid fuel firing installation at an approximate cost of $500,000 (1984 Canadian), with a design capacity of 20% supplementation.

This system is operated in a similar procedure as the pilot program. The shive is transported by truck from the stock pile and dumped into either of two live bottom hoppers, each having a capacity of 4 tonne of materials (Figure 3). These feeders meter the flax onto a 30-inch wide rubber belt conveyor (Figure 3). Located at the lower end of the belt conveyor is a weigh scale and associated electronics which will vary the speed of the feeders to maintain a constant tonnage rate on the conveyor. The belt conveyor discharges the material into a 250 H.P. hammermill which reduces the size of the shive to almost a powder (Figure 4). From the hammermill the crushed shive is fed through a rotary air lock onto the same 4 inch steel pipeline used for the pilot system, and conveyed pneumatically to the rotary kiln. A large dust collector air-sweeps the hammermill and de-dusts each of the feeders and transfer points.

To date a maximum substitution rate of 18% has been achieved, with an on-stream factor of about 60%.

Bridging of the shives continues to be a problem particularly in the hopper above the hammermill. Genstar plans to change the slope angle of the hopper; if this does not alleviate the problem, mechanical debridging may be introduced.

Moisture condensation and freezing in the dust collector assembly has been a problem during colder operating periods. Excess heat from the kiln area will be ducted into the collector to prevent this.

Finally, the company plans to increase the carrier air flow rate to decrease drop-out and, if necessary, will increase the size of the pneumatic line.

Assuming that a fuel substitution rate of 20% can be achieved and maintained at a 1983 cement production level a simple payback period of less than one year is achievable. This estimate allows for conservative operating costs of $25.00/tonne of shives which includes delivered fuel cost, labour, maintenance, power consumption and a generous contingency.

No additional costs for burner modification or environmental compliance are assumed necessary at this time (no increase in particulates emmissions from the kiln has been observed).

Even when contingencies are allowed for, such as the possibility of reduced kiln refractory and chain life, requirements for occupational health and safety measures (dust suppression, fire safety), environmental compliance, etc., the use of flax shives remains more economically attractive than the other fuels tested.

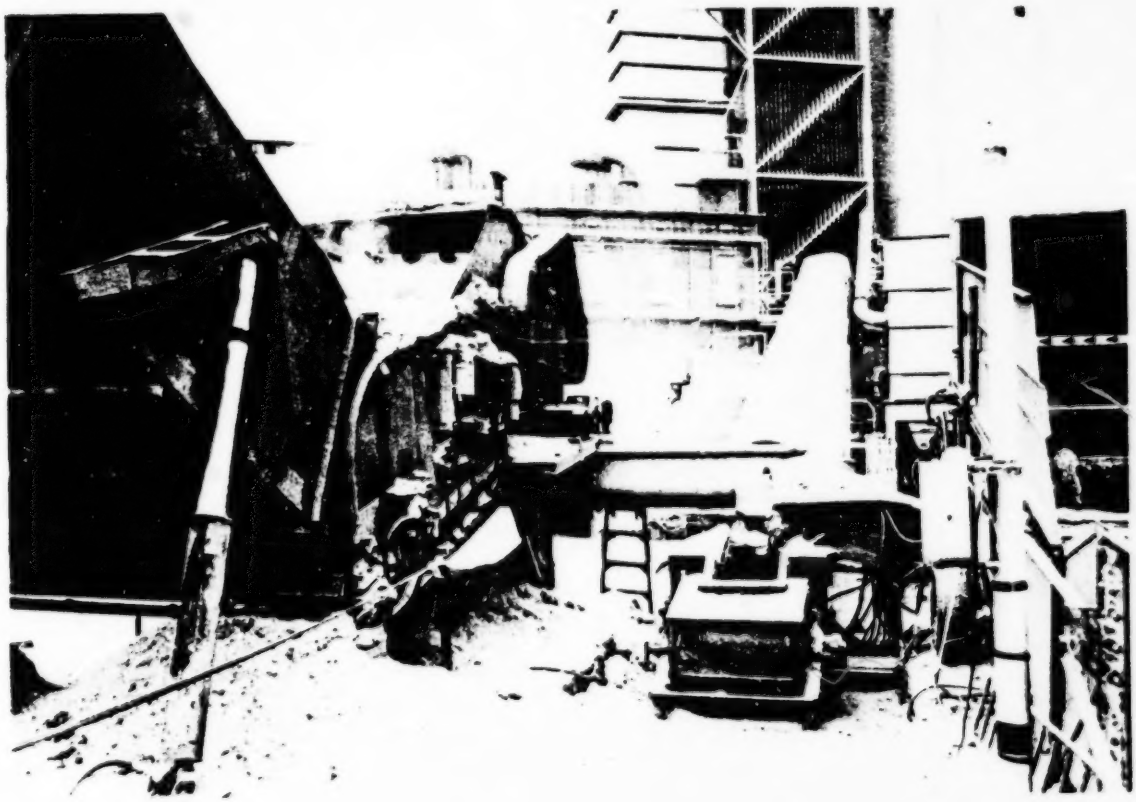


FIGURE 3 LIVE BOTTOM HOPPER (FOREGROUND) AND WEIGHBELT CONVEYOR

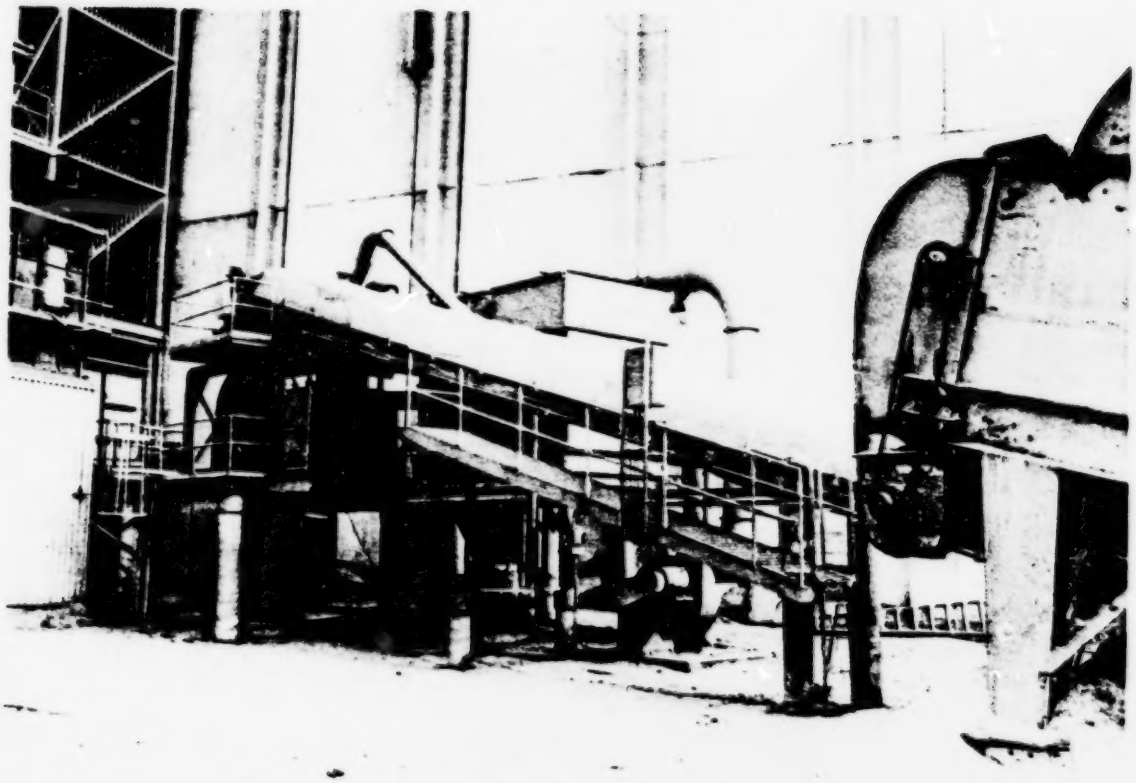


FIGURE 4

GENSTAR SOLID FUEL FEED SYSTEM

10.0 REFERENCES

1. Robb, A.F., and Luka, R; "Use of Refuse Derived Fuel as a Supplementary Fuel in Cement Kilns" p. 18, Energo '83 Conference Papers, Ontario Ministry of Energy (1983).

2. Experiments conducted at Canada Cement Lafarge. Private communication with S. Giorur, Technical Services Branch, Environmental Protection Program Directorate, Environment Canada.

3. Hazelwood, D.L. et al; "Assessment of Waste Fuel Use in Cement Kilns", U.S. EPA Report No. 68-03-2586 (1981).

4. Mix, T.W. and Murphy, B.L.; "Risks Associated with Waste Fuel Use in Cement Kilns", Environmental Progress 3 (1), 64 (1984).

5. Saxena, P.K. and Buchanen, L.C.; "Heat Recovery by Burning of Agricultural Residues" Can. Soc. Agric. Eng., Vancouver, B.C. Paper No. 82-106 (1982)